



The Moment of formation of a Black Hole in Gamma-Ray Bursts

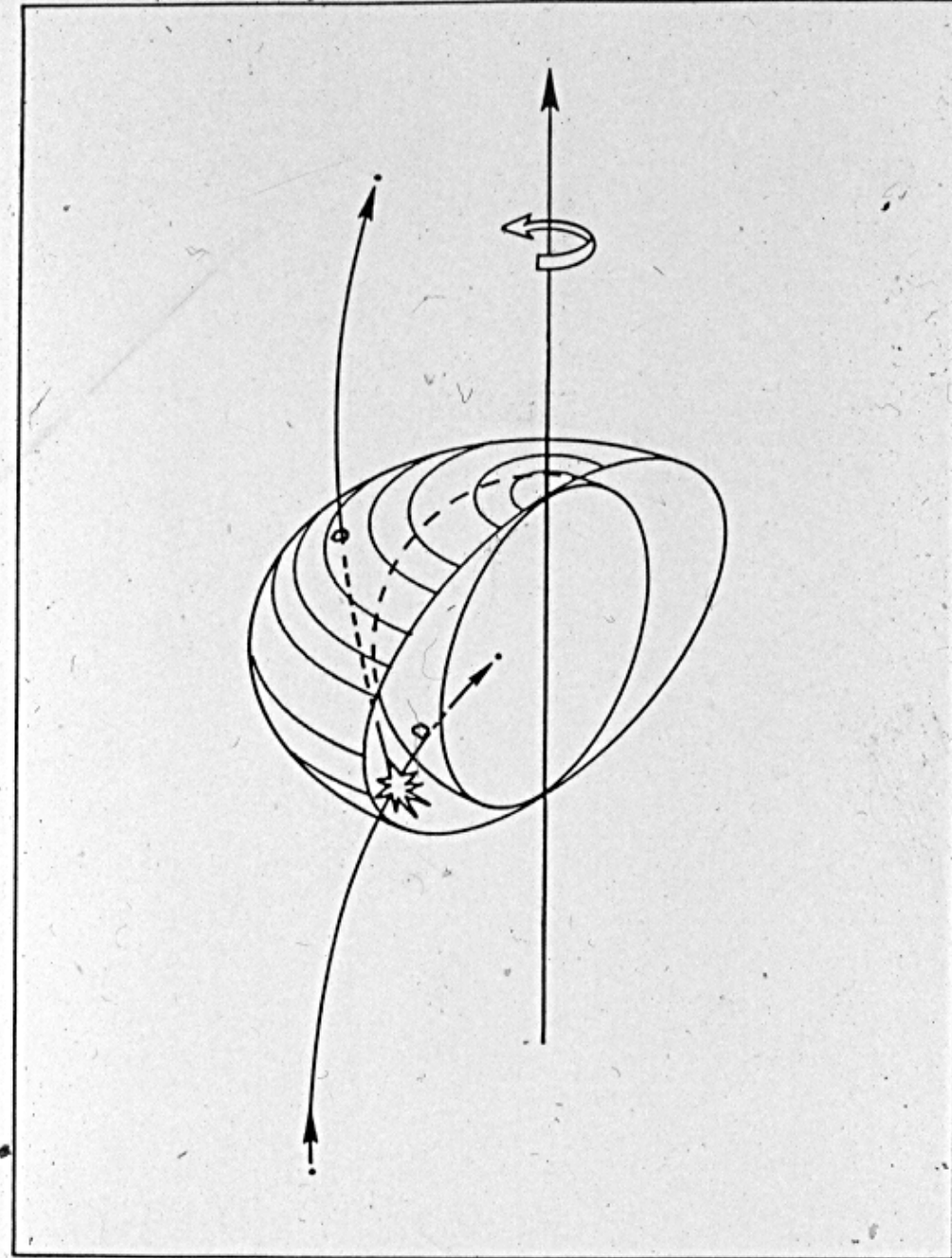
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and collaborators

ICRANet Pescara – Nice – Rio – Rome – Yerevan
Università “La Sapienza” - Rome

DAMTP – Cambridge, UK – June 21th, 2017



The Ergosphere of a Kerr Black Hole



Ergosphere of a rotating black hole. The region between the surface of infinite redshift (outer) and the event horizon (inner), here shown in a cutaway view, is called the "ergosphere." When a particle disintegrates in this region and one of the fragments falls into the black hole, the other fragment can escape to infinity with more rest plus kinetic energy than the original particle.

Figure 5



The Black Hole Mass-Energy Formula

$$m^2 = \left(m_{ir} + \frac{e^2}{4m_{ir}} \right) + \frac{L^2}{4m_{ir}^2}$$

$$S = 16\pi m_{ir}^2$$

$$\delta S = 32\pi m_{ir} \delta m_{ir} \geq 0$$

Christodoulou, *Phys. Rev. Lett.*, 25 (1970) 1596 (received September 17th, 1970)

Christodoulou, Ruffini, *Phys. Rev. D*, 4 (1971) 3552 (received March 1st, 1971)

Hawking, *Phys. Rev. Lett.*, 26 (1971) 1344 (received March 11th, 1971)

Hawking, *Commun. Math. Phys.*, 25 (1972) 152 (received October 15th, 1971)



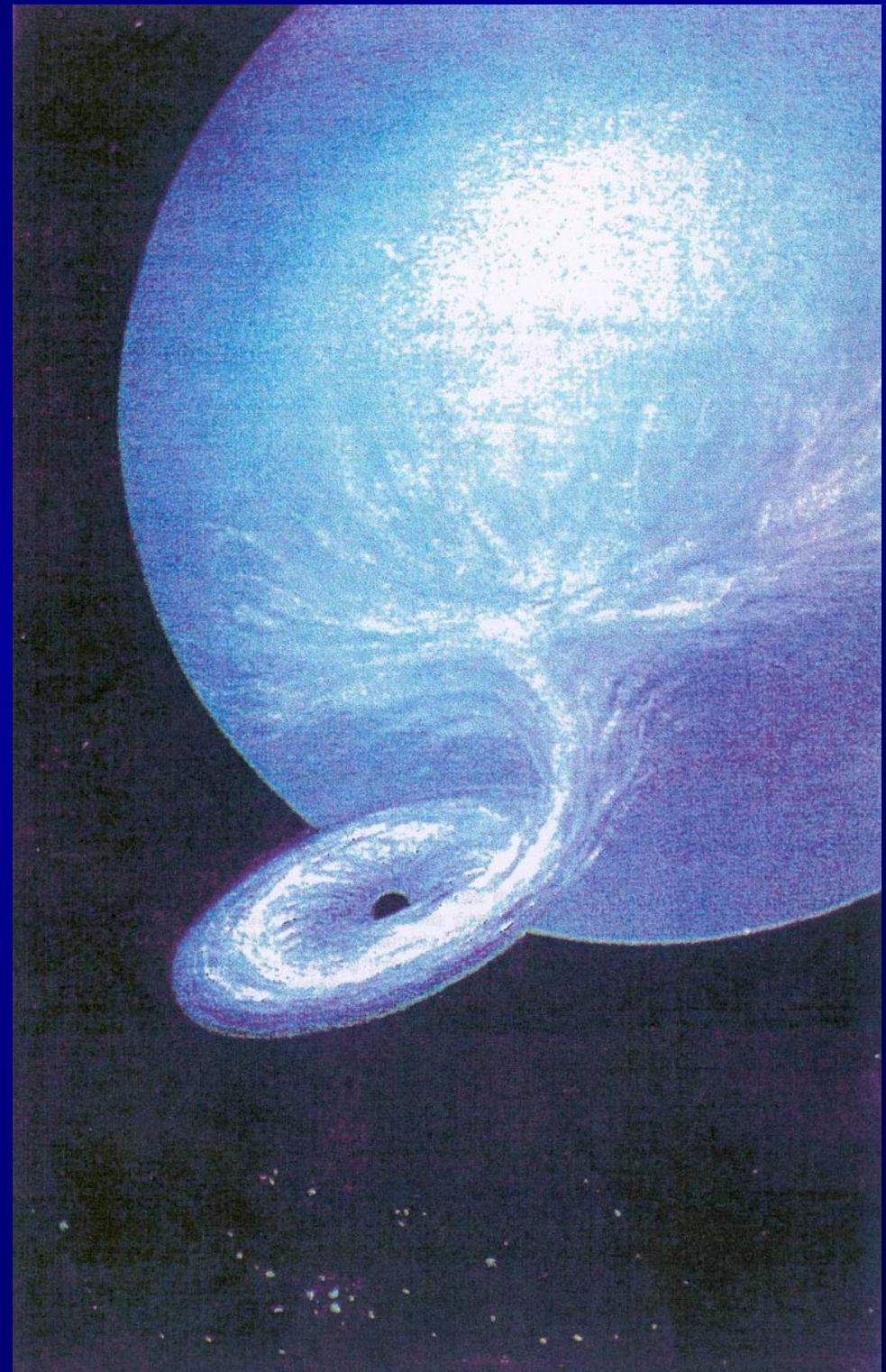
The identification of the first black hole in our galaxy: Cygnus X-1

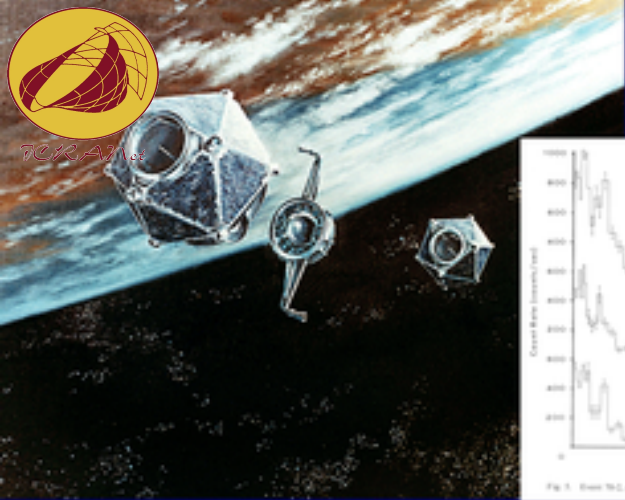
$$\begin{aligned}\Phi &= 10^{37} \text{ erg/s} = 10^4 L_{\odot} \\ &= 0.01(dm/dt)_{\text{acc}} c^2\end{aligned}$$

Absence of pulsation due to uniqueness of Kerr-Newmann black holes

$$M > 3.2 M_{\odot}$$

Leach & Ruffini, 1973





$E=10^{54}$ erg

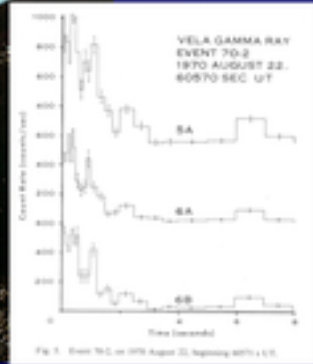
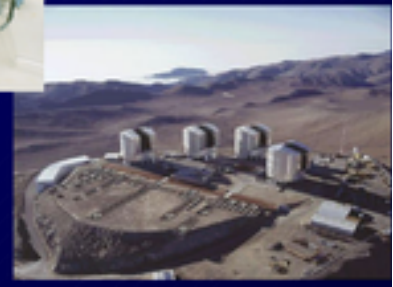
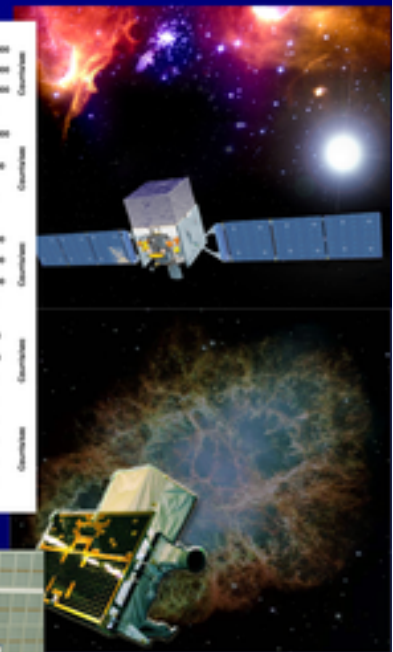
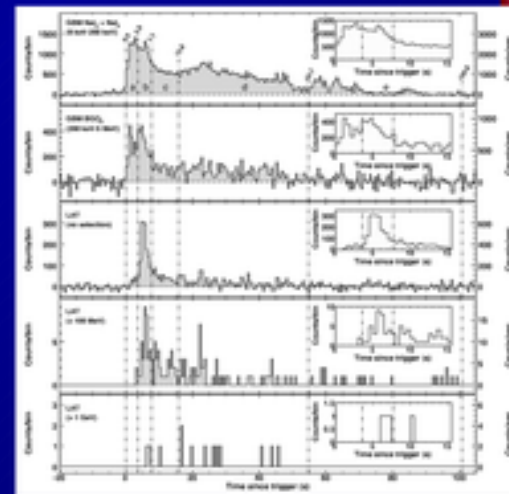
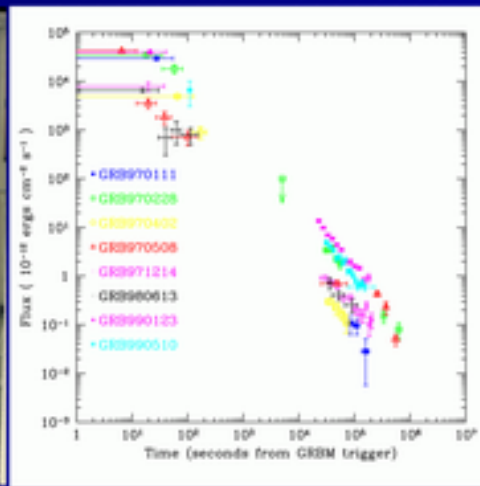
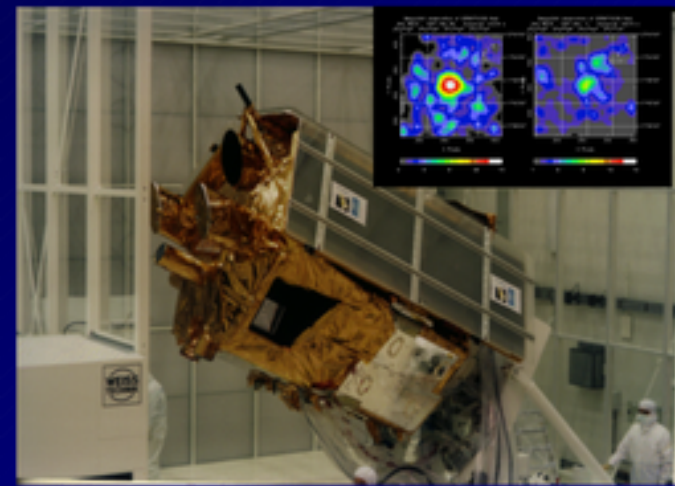
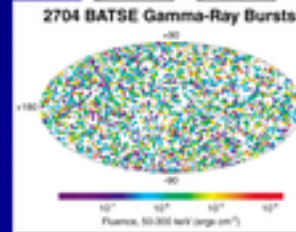
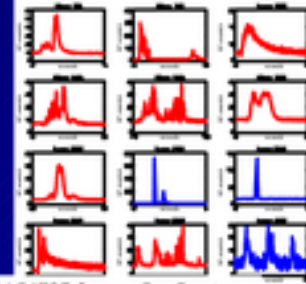
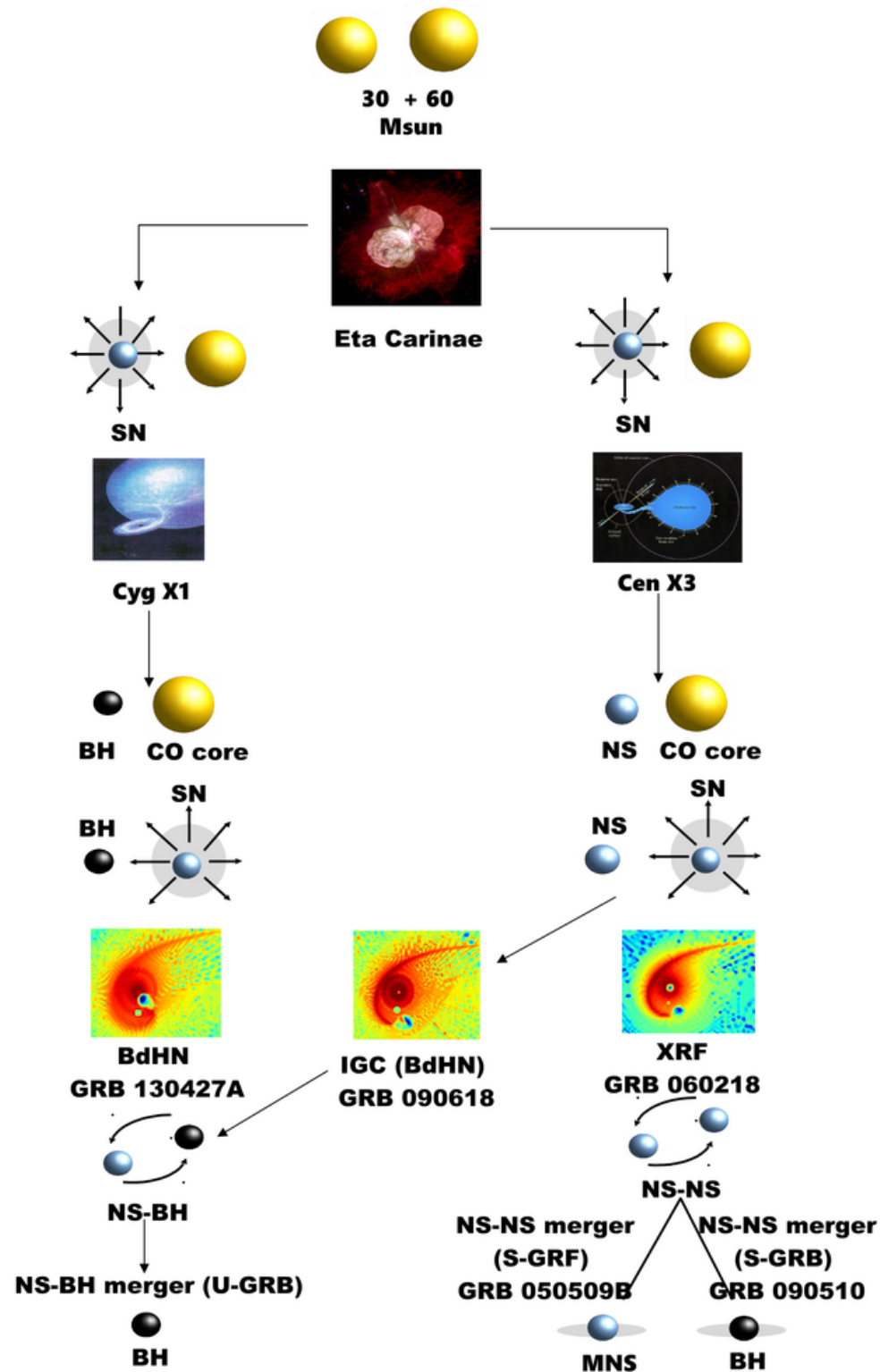


Fig. 1. Event 70-2, on 1970 August 22, beginning with a 100



A common evolutionary scenario for short and long GRBs



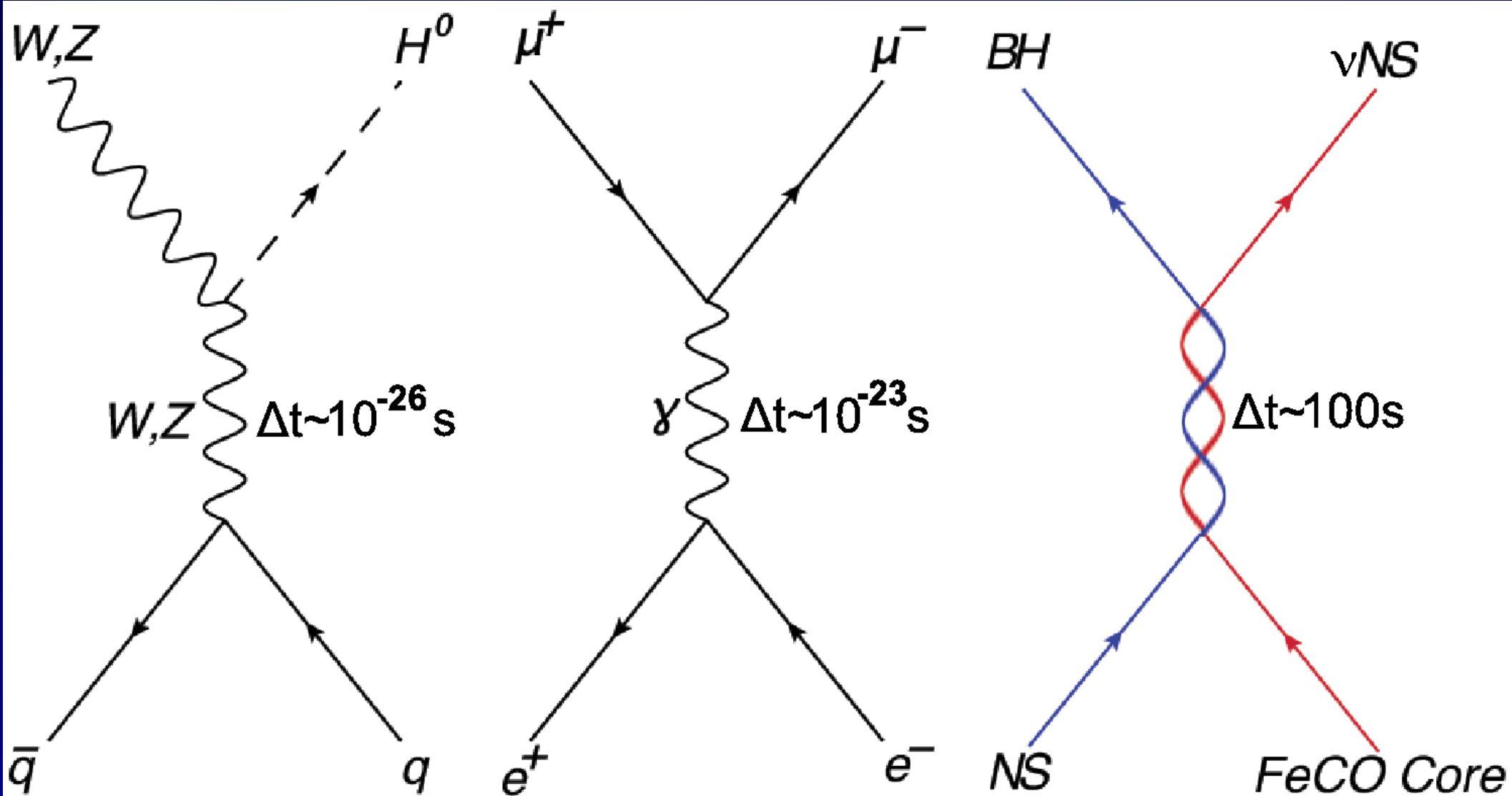
Rueda, Ruffini, *ApJL*, **758** (2012) L7

Becerra, Cpolletta, Fryer, Rueda, Ruffini, *ApJ*, **812** (2015) 100

Fryer, Oliveira, Rueda, Ruffini, *Phys. Rev. Lett.*, **115** (2015) 23

Ruffini, Rueda, et al., *ApJ*, **832** (2016) 136

S-Matrix vs. Cosmic Matrix





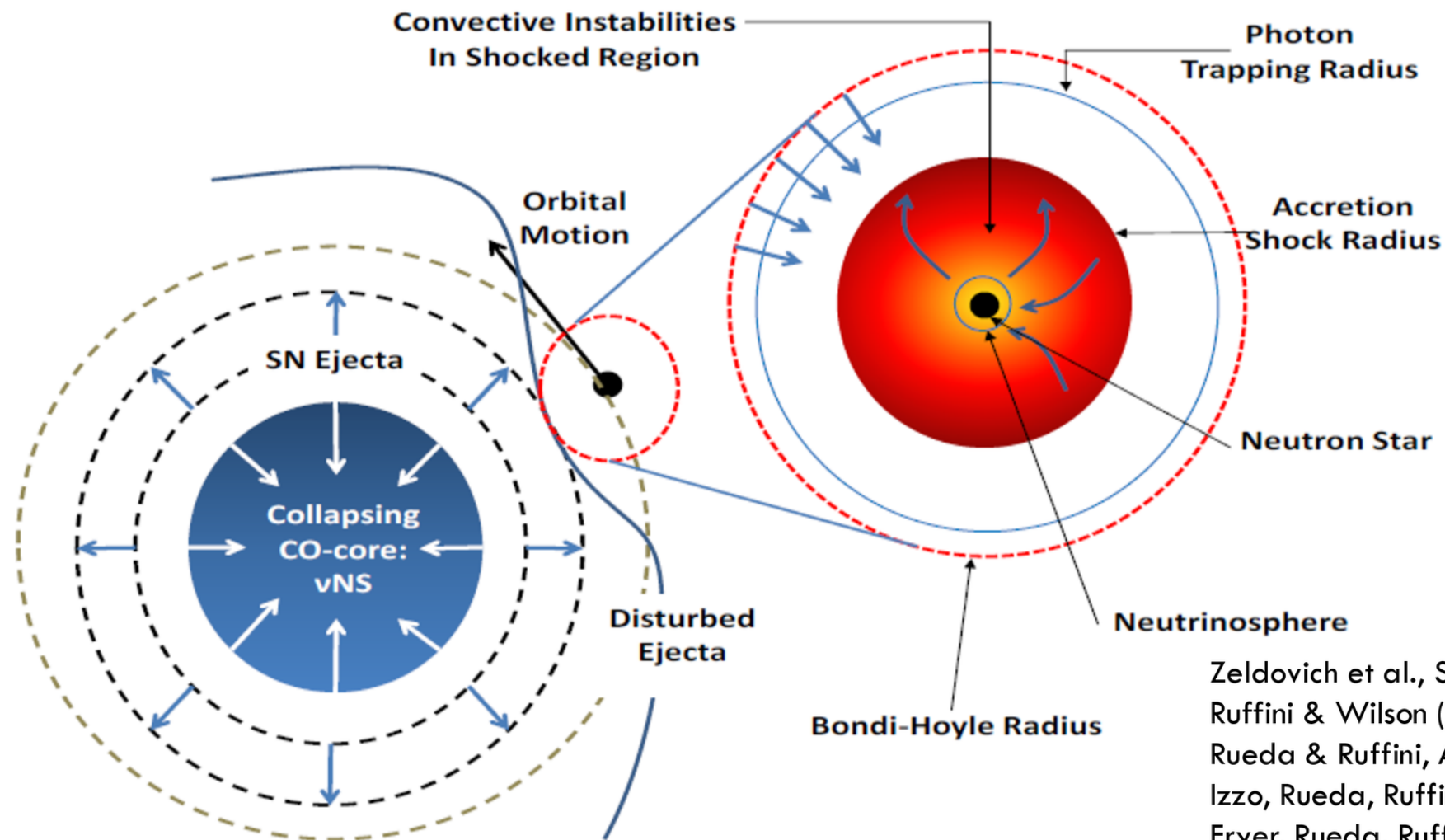
Recent ICRANet research topics

- **First Topic:** L. Becerra, C. L. Bianco, C. L. Fryer, J. A. Rueda, R. Ruffini; “On the induced gravitational collapse scenario of gamma-ray bursts associated with supernovae”; *Ap.J.* 833 (2016) 107 - (arXiv: 1606.02523)
- **Second Topic:** R. Ruffini, Y. Wang, Y. Aimuratov, et al.; “X-ray Flares in Early Gamma-ray Burst Afterglow”; *Ap.J.* submitted (arXiv: 1704.03821)
- **Third Topic:** Y. Aimuratov, R. Ruffini, M. Muccino, et al.; “GRB 081024B and GRB 140402A: two additional short GRBs from binary neutron star mergers”; *Ap.J.* in press (arXiv: 1704.08179)
- **Fourth Topic:** J. F. Rodriguez, J. A. Rueda, R. Ruffini; “Strong-field gravitational-wave emission in Schwarzschild and Kerr geometries: some general considerations”; *PRD*, submitted (arXiv: 1706.06440)



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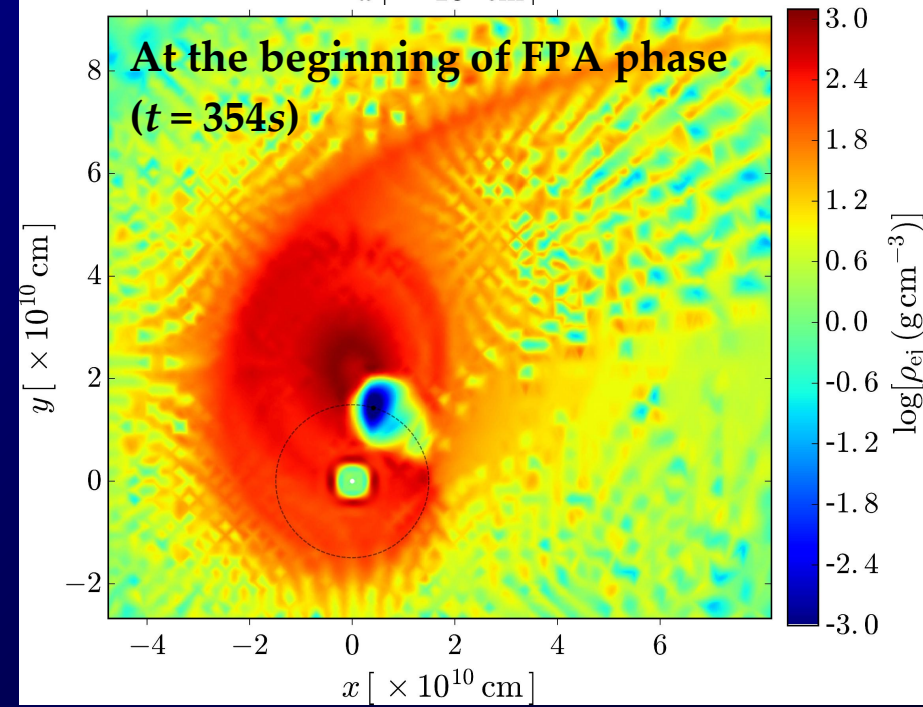
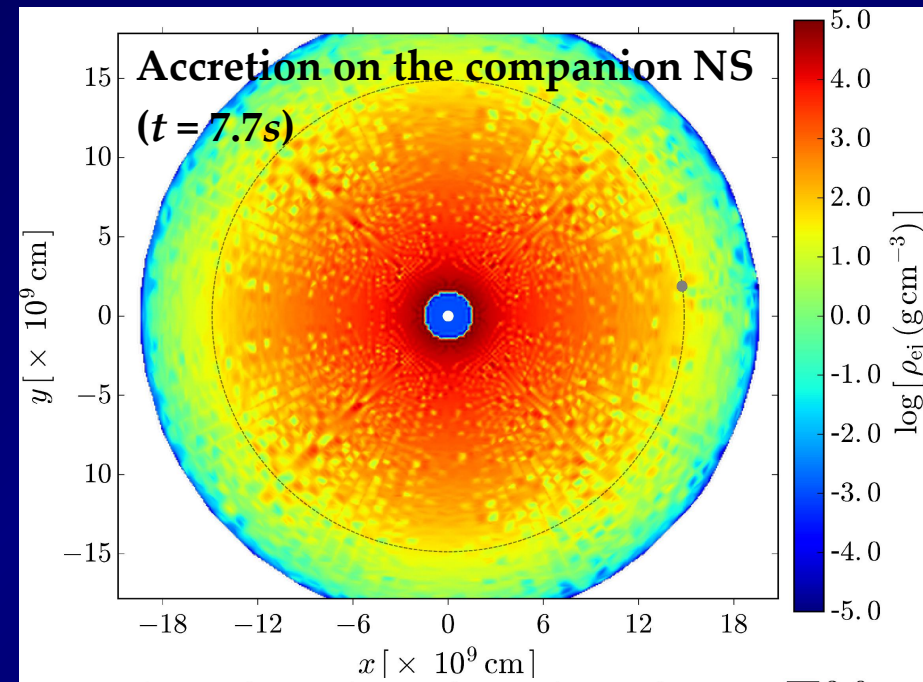
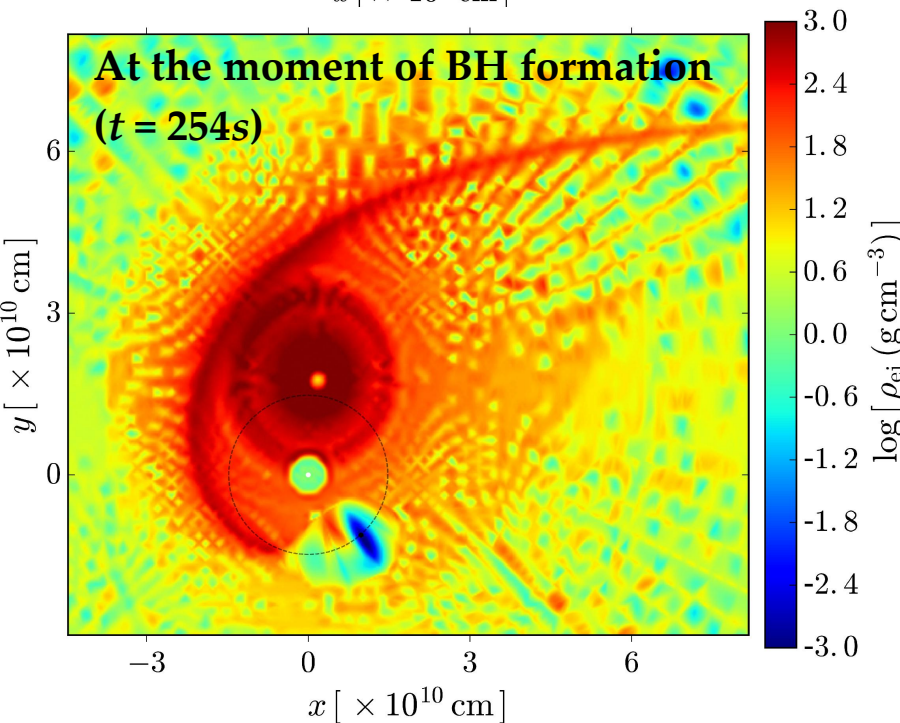
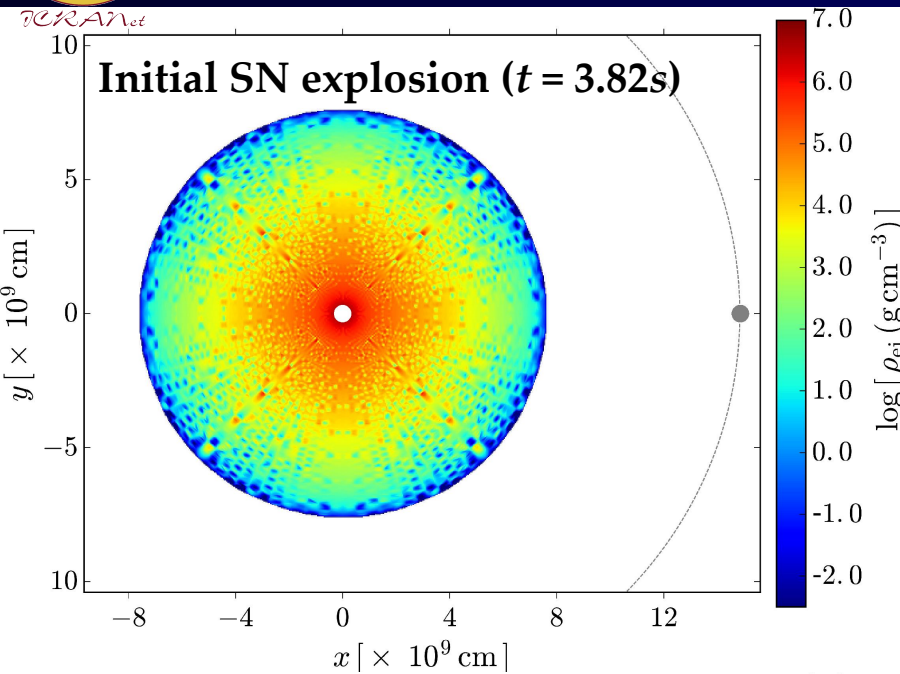
Hypercritical Accretion, Binary-Driven HNe, and IGC



Zeldovich et al., Sov. Astron. (1972)
 Ruffini & Wilson (1973)
 Rueda & Ruffini, ApJL (2012)
 Izzo, Rueda, Ruffini, A&AL (2012)
 Fryer, Rueda, Ruffini, ApJL (2014)

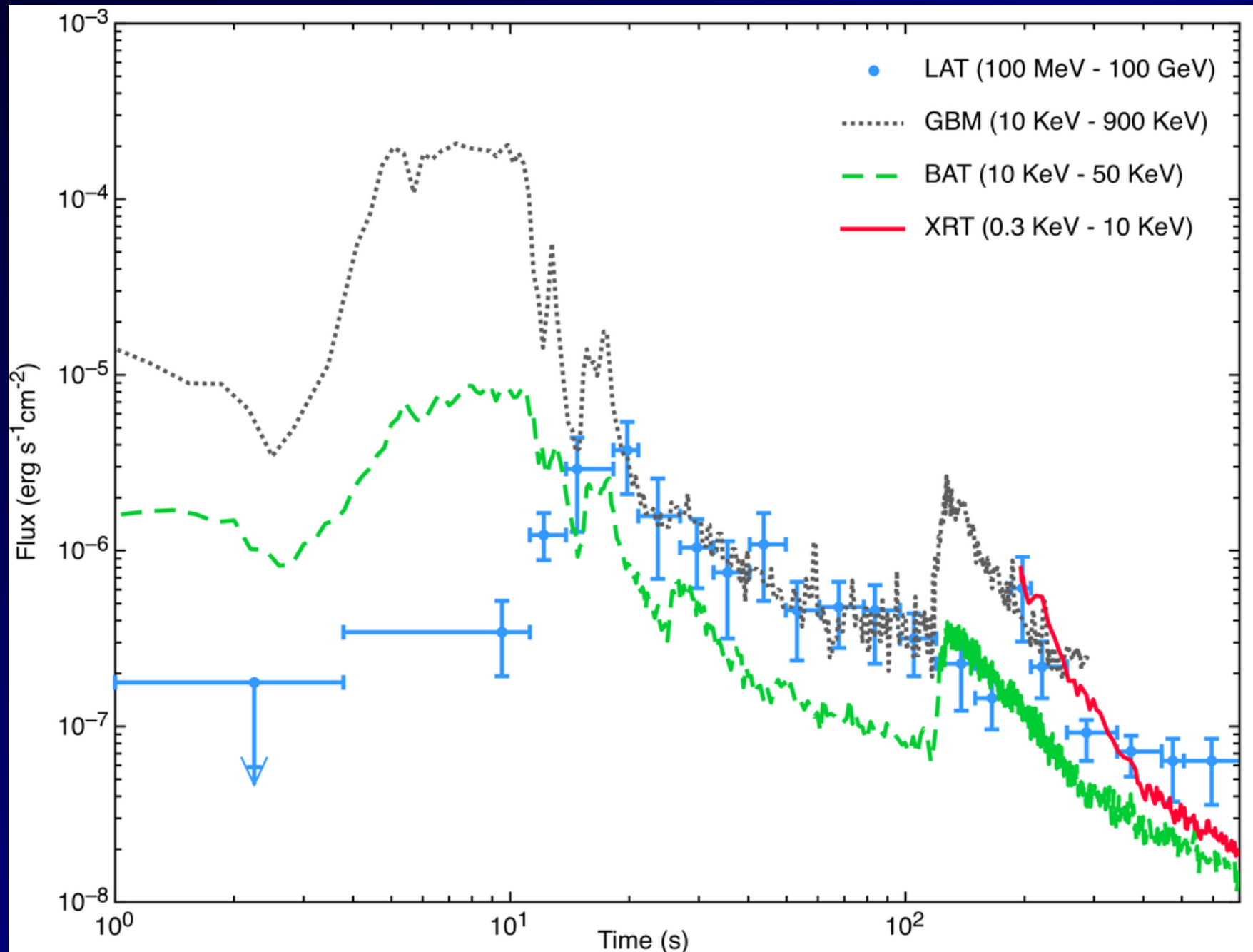


Simulation of BdHNe





Onset of GeV emission in BdHN 130427A

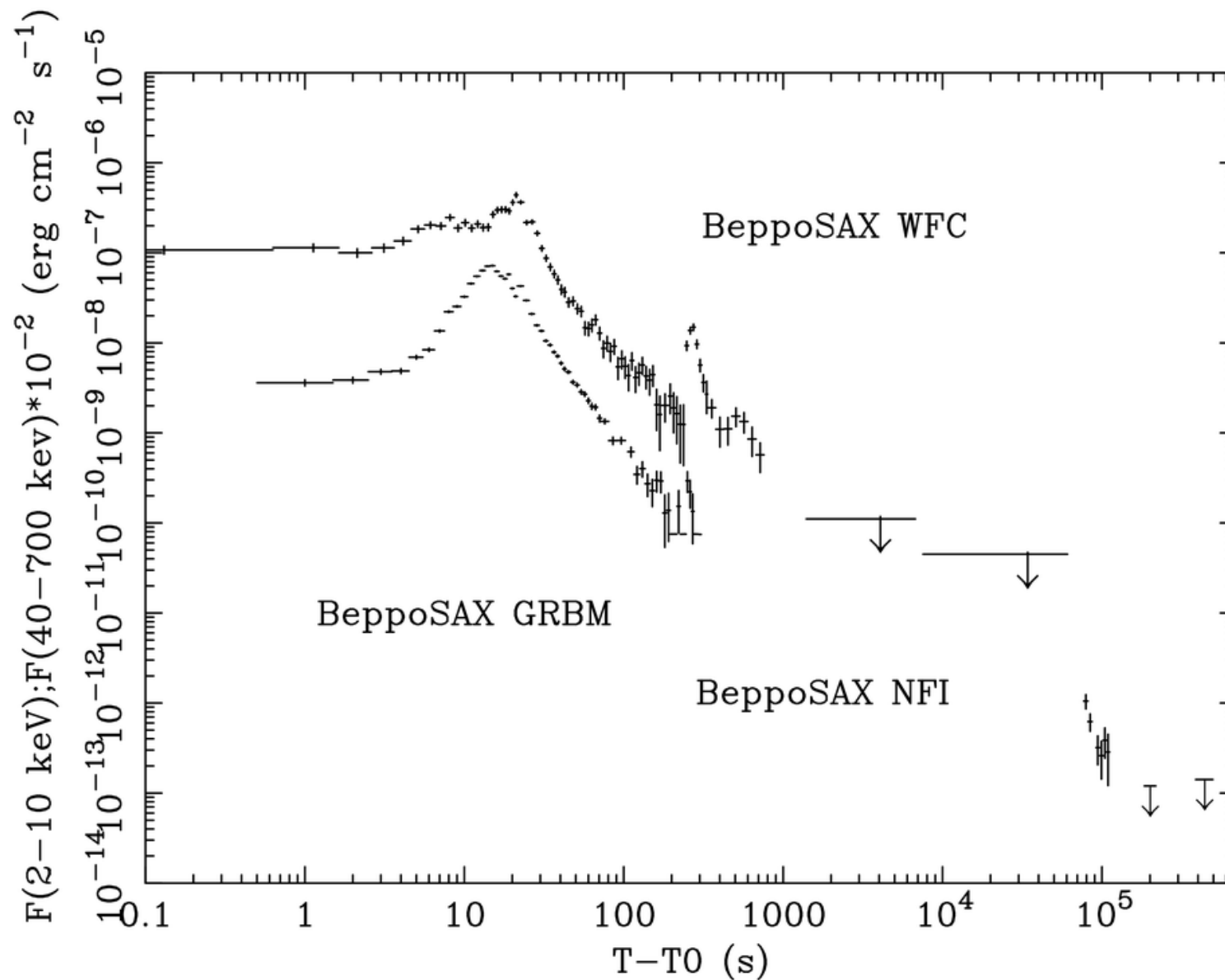




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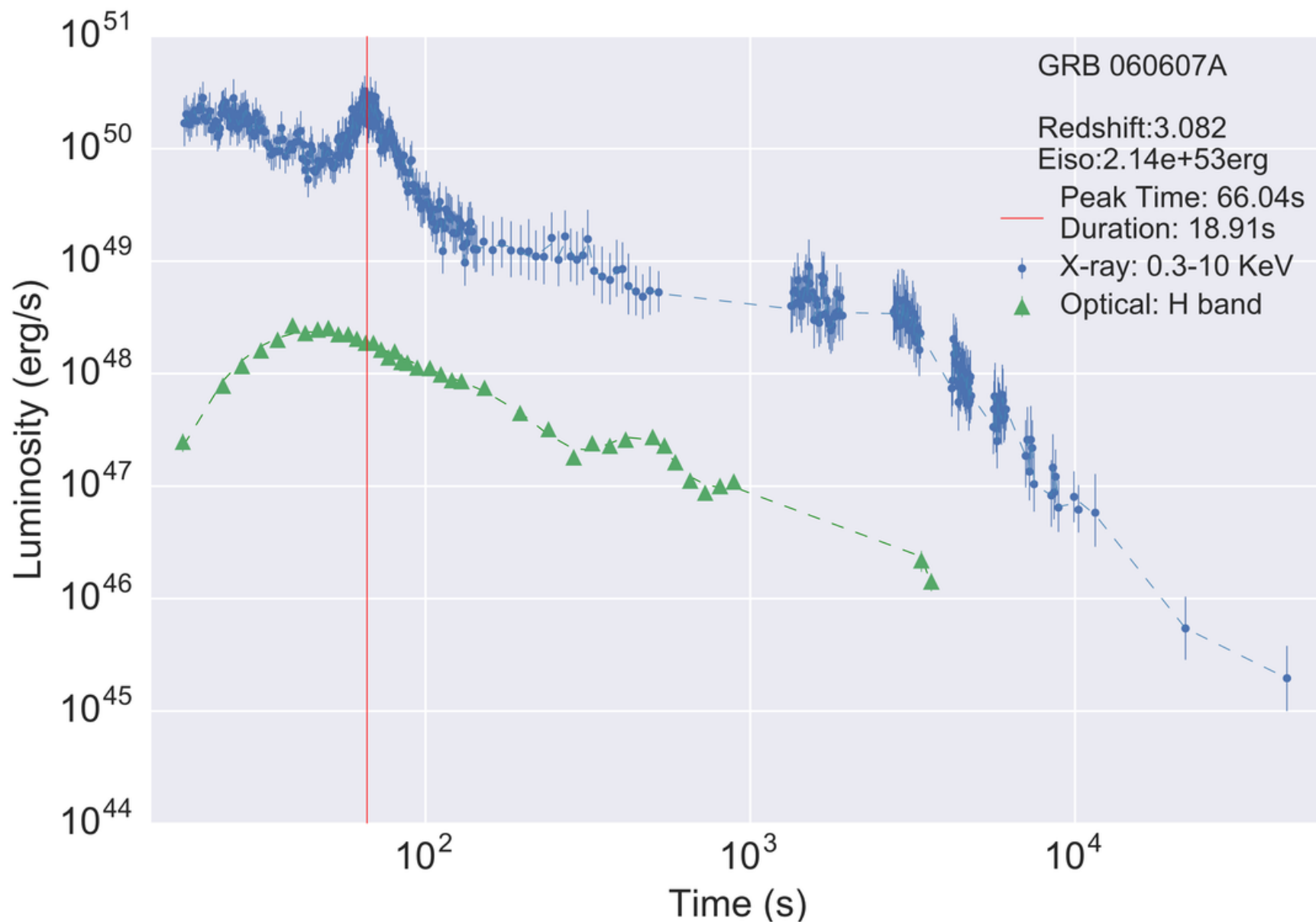


The first X-ray flare observed by BeppoSAX

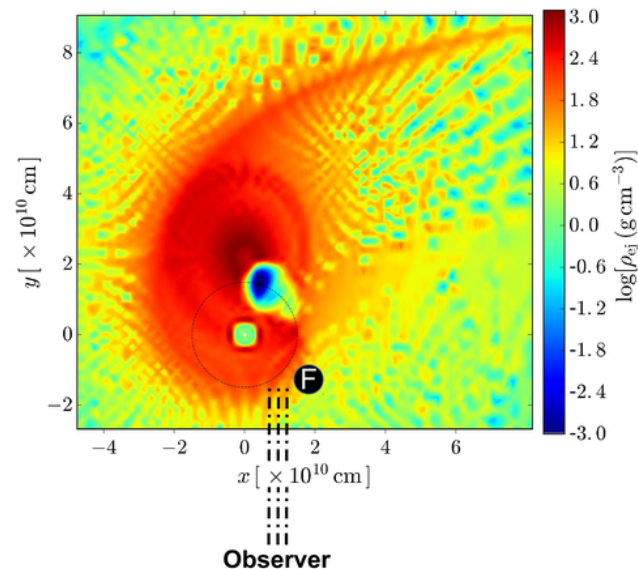
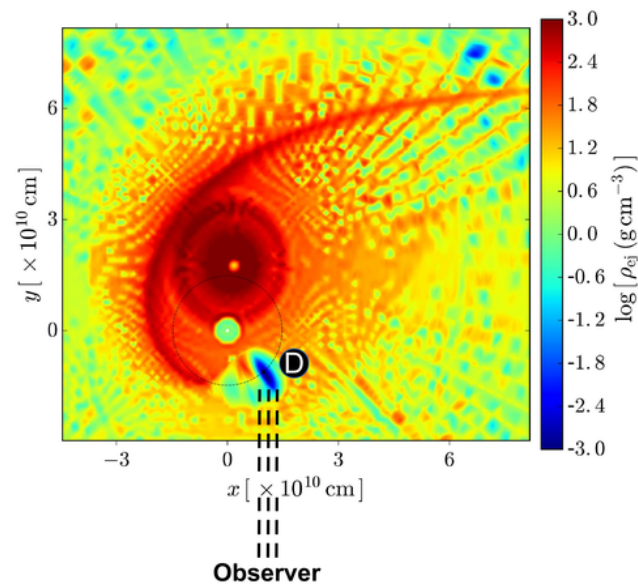
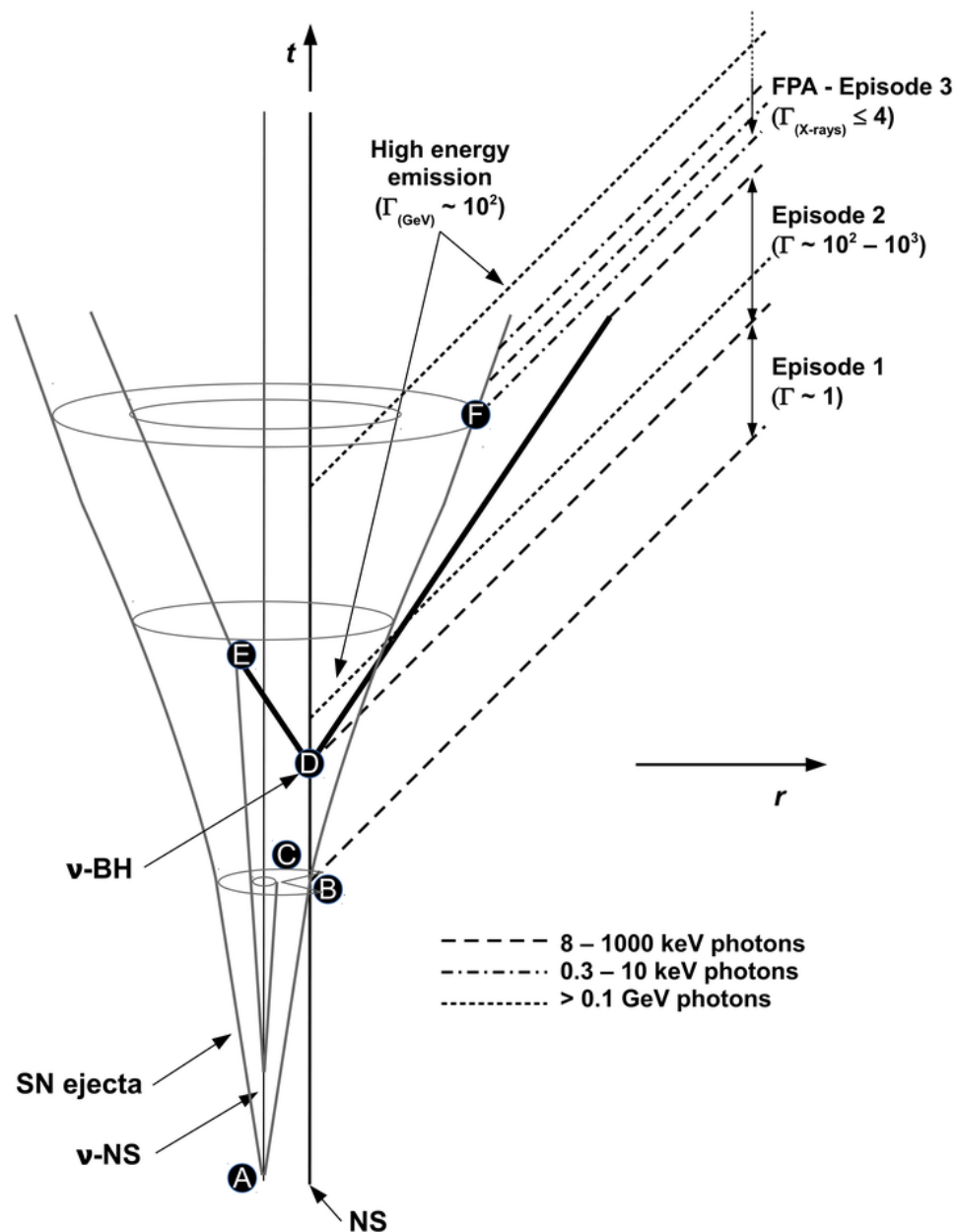




X-Ray Flare in BdHN 060607A



BdHN spacetime diagram

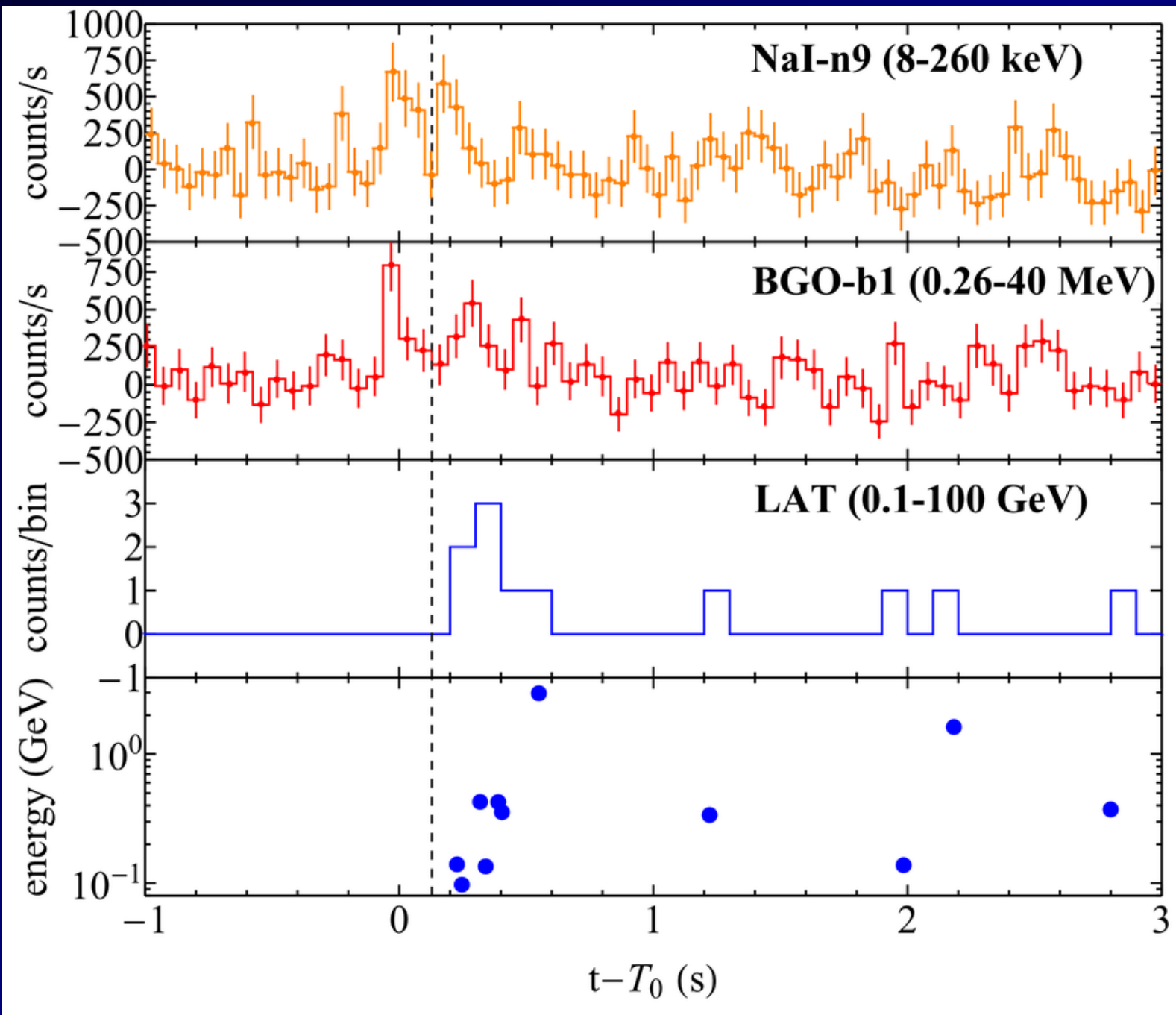




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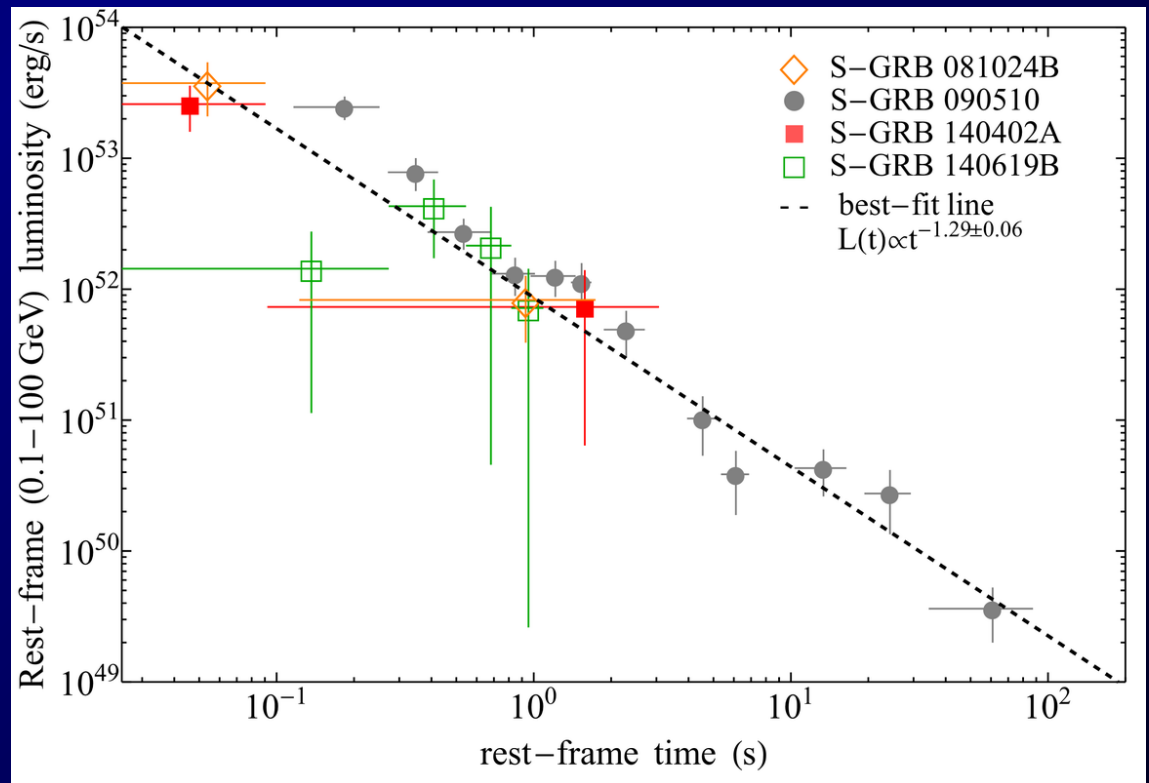
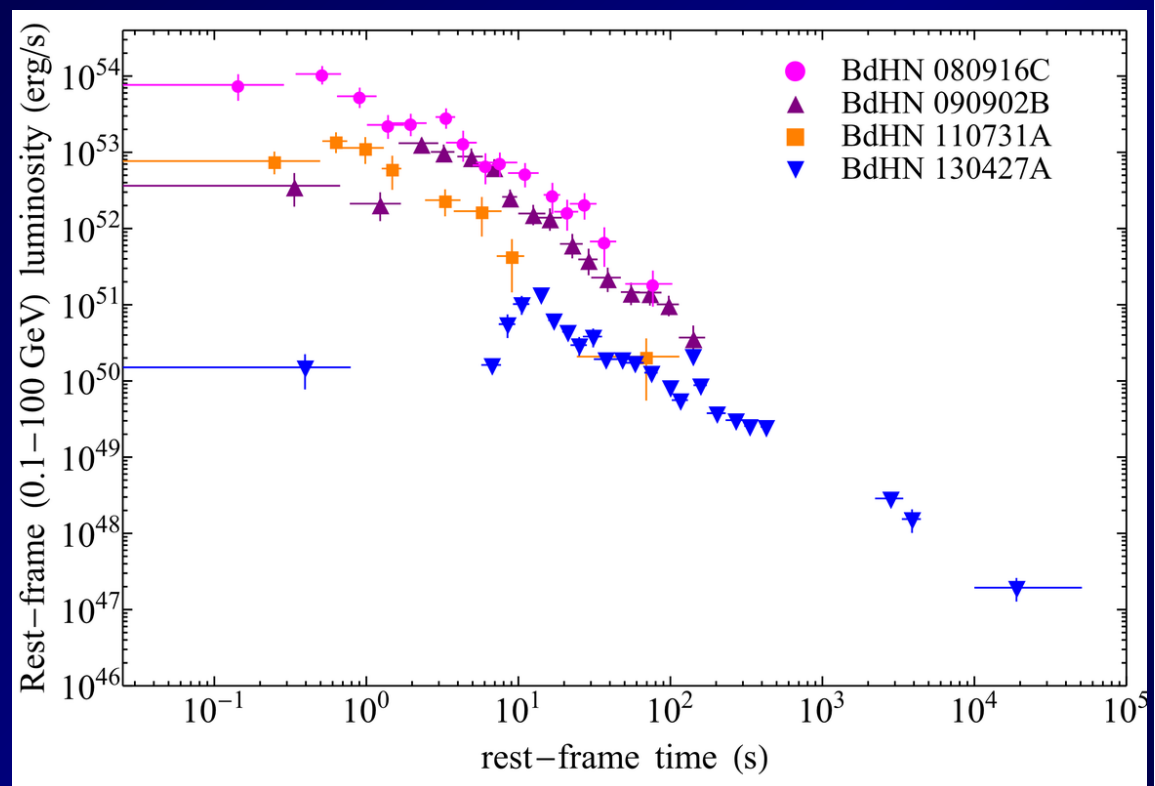


Onset of GeV emission in S-GRB 081024B

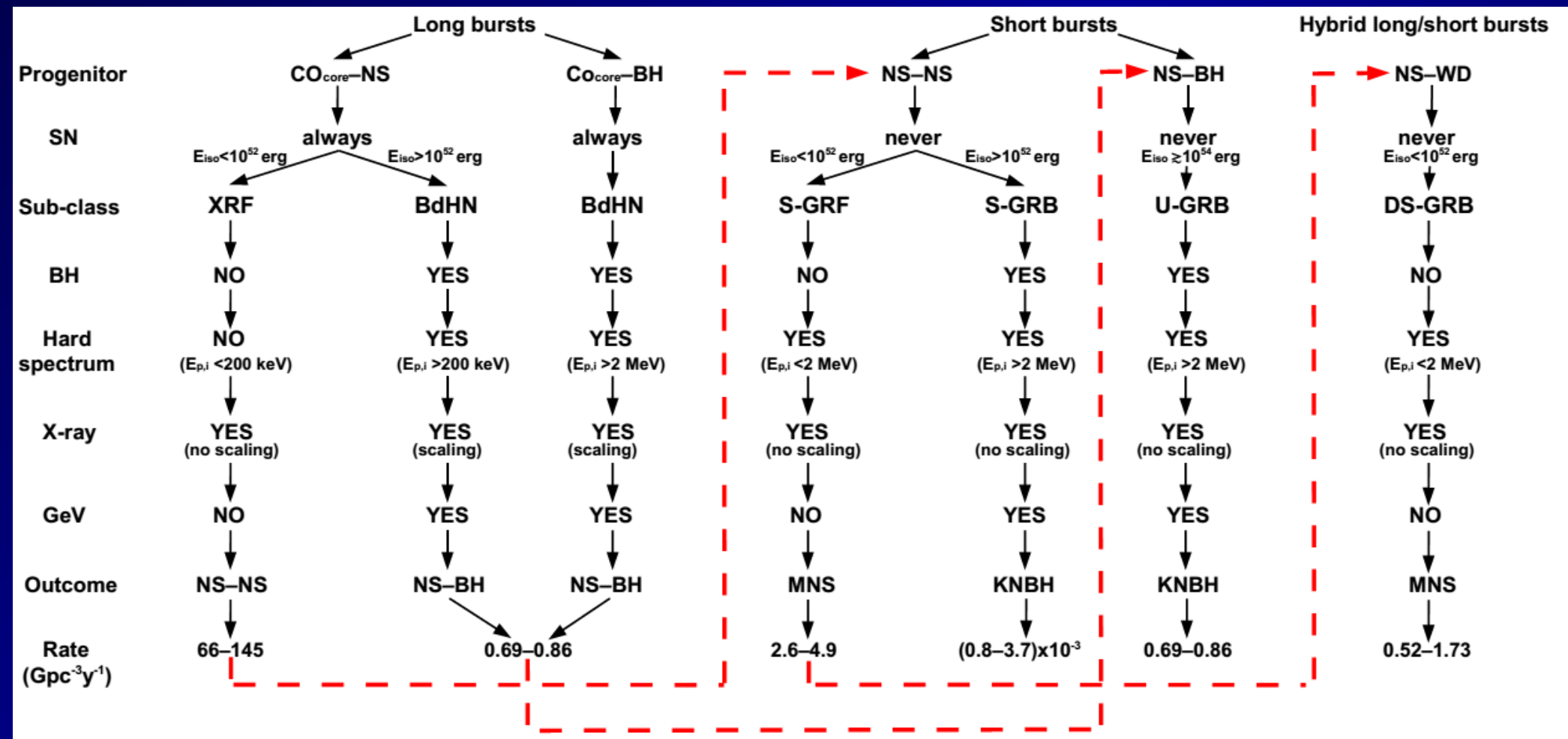




GeV emission in BdHNe and S-GRBs



Seven Different GRB families

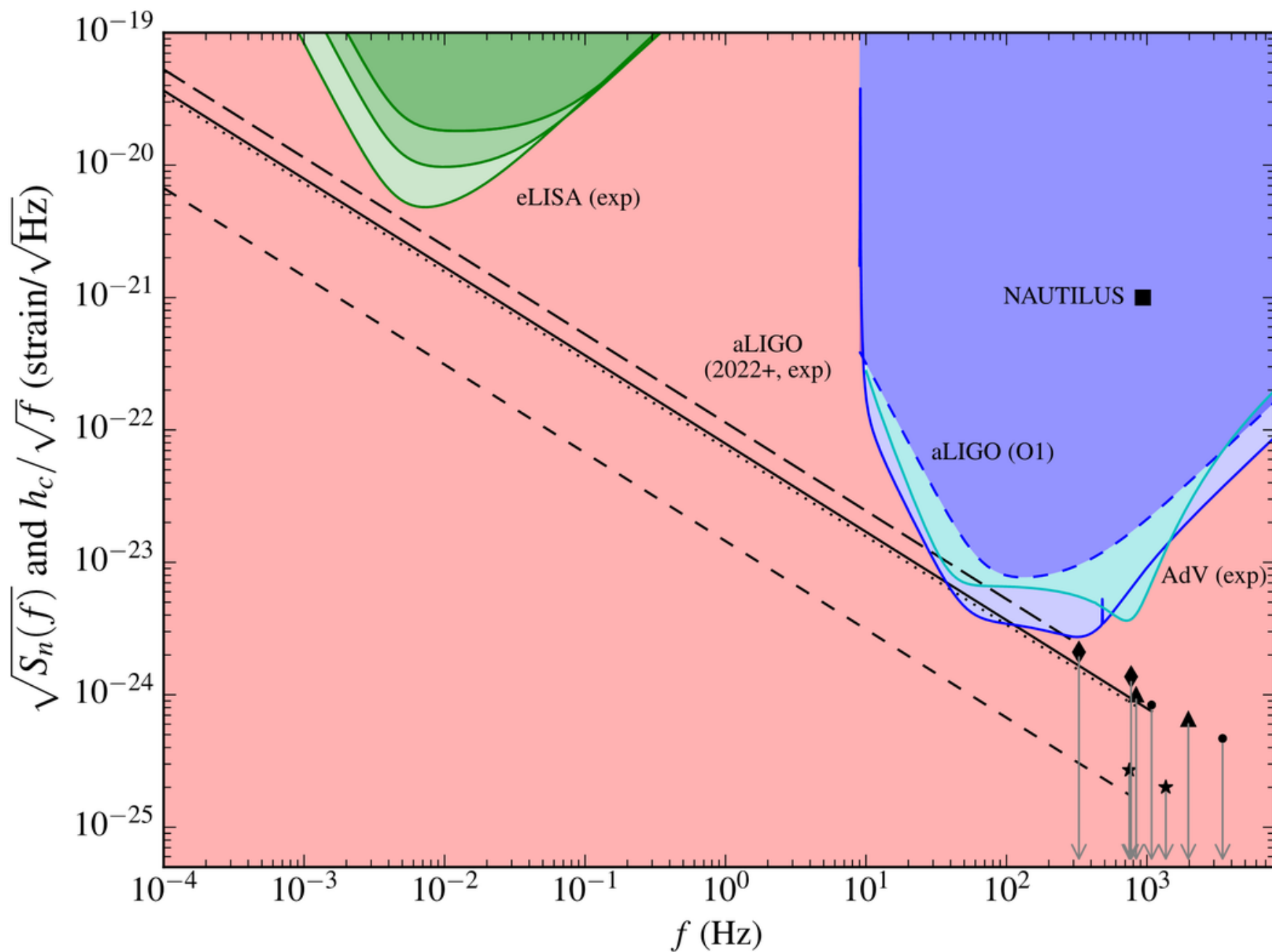




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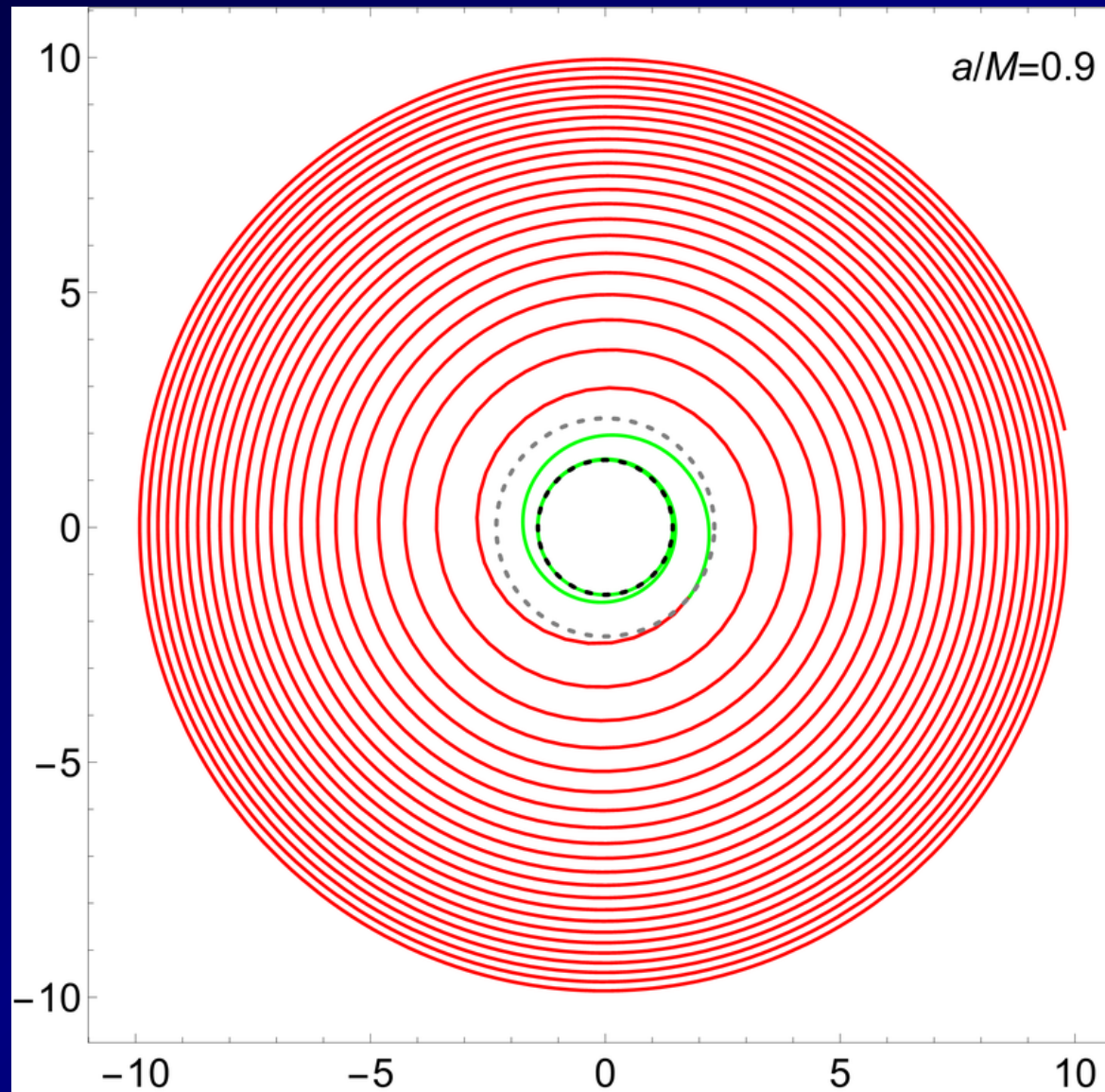


GRBs and gravitational wave detectors



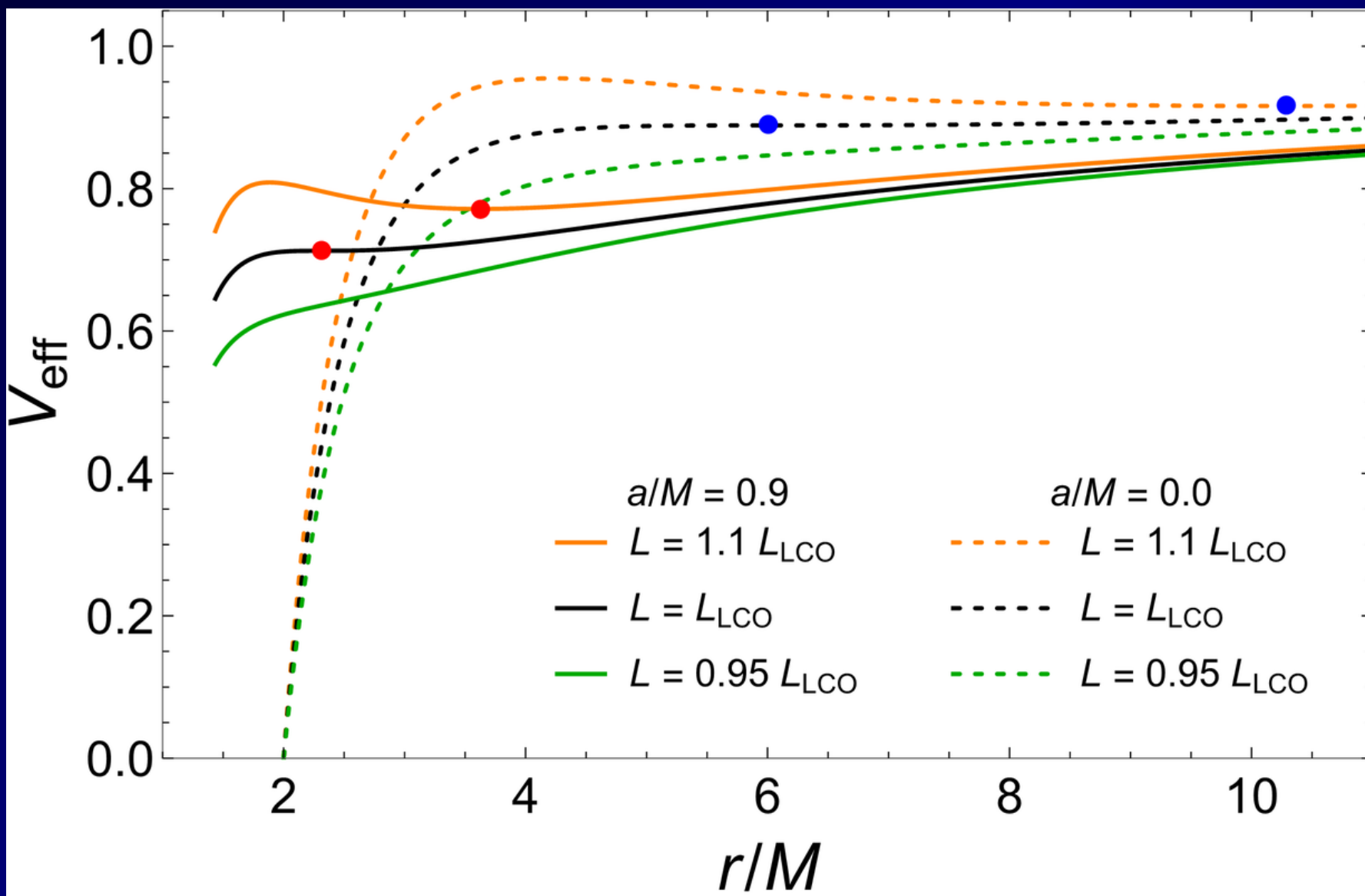


Helicoidal drifting sequence around a Kerr Black Hole





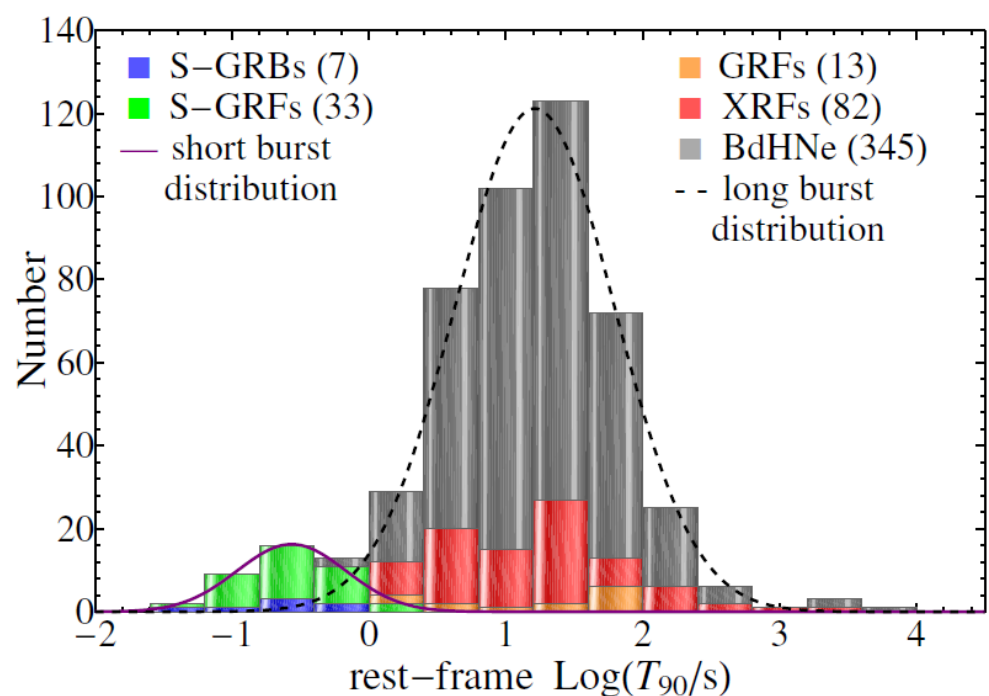
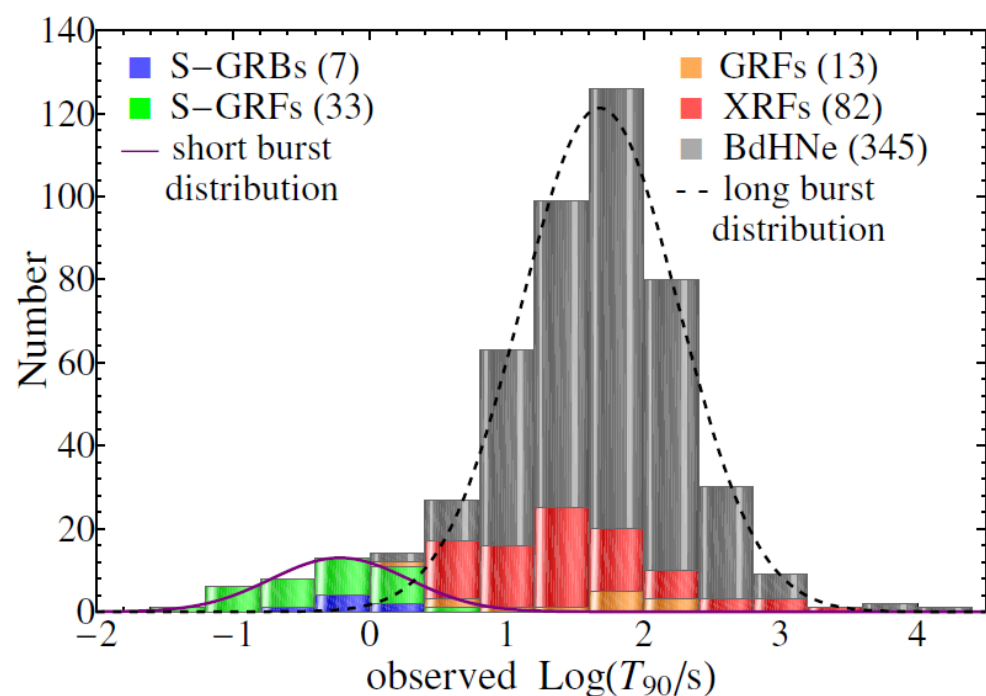
Effective potential in Schwarzschild and Kerr geometries





Summary of the seven different GRB families

	Subclass	number	<i>In-state</i>	<i>Out-state</i>	T_{90} (s)	$E_{p,i}$ (MeV)	E_{iso} (erg)	$E_{iso,X}$ (erg)	$E_{iso,Gev}$ (erg)	ρ_{GRB} (Gpc ⁻³ yr ⁻¹)
I	XRFs		CO _{core} -NS	ν NS-NS	$\sim 2-10^3$	$\lesssim 0.2$	$\sim 10^{48}-10^{52}$	$\sim 10^{48}-10^{51}$	—	100^{+45}_{-34}
II	BdHNe		CO _{core} -NS	ν NS-BH	$\sim 2-10^2$	$\sim 0.2-2$	$\sim 10^{52}-10^{54}$	$\sim 10^{51}-10^{52}$	$\lesssim 10^{53}$	$0.77^{+0.09}_{-0.08}$
III	BH-SN		CO _{core} -BH	ν NS-BH	$\sim 2-10^2$	$\gtrsim 2$	$> 10^{54}$	$\sim 10^{51}-10^{52}$	$\gtrsim 10^{53}$	$\lesssim 0.77^{+0.09}_{-0.08}$
IV	S-GRFs		NS-NS	MNS	$\lesssim 2$	$\lesssim 2$	$\sim 10^{49}-10^{52}$	$\sim 10^{49}-10^{51}$	—	$3.6^{+1.4}_{-1.0}$
V	S-GRBs		NS-NS	BH	$\lesssim 2$	$\gtrsim 2$	$\sim 10^{52}-10^{53}$	$\lesssim 10^{51}$	$\sim 10^{52}-10^{53}$	$\left(1.9^{+1.8}_{-1.1}\right) \times 10^{-3}$
VI	U-GRBs		ν NS-BH	BH	$\ll 2$	$\gtrsim 2$	$> 10^{52}$	—	—	$\gtrsim 0.77^{+0.09}_{-0.08}$
VII	GRFs		NS-WD	MNS	$\sim 2-10^2$	$\sim 0.2-2$	$\sim 10^{51}-10^{52}$	$\sim 10^{49}-10^{50}$	—	$1.02^{+0.71}_{-0.46}$



Thanks to...

Y. Aimuratov, L. Becerra, D. Begue, R. Belvedere, M.G. Bernardini, C.L. Bianco, L. Caito, R. Camargo, P. Chardonnet, C. Cherubini, F. Cipolletta, A. Corsi, M.G. Dainotti, T. Damour, G. De Barros, M. Enderli, S. Filippi, F. Fraschetti, C. Fryer, R. Guida, L. Izzo, M. Karlica, R. Kerr, M. Kovacevic, L. Li, G. Mathews, J.D. Melon Fuksman, R. Moradi, M. Muccino, F. G. Oliveira, B. Patricelli, A.V. Penacchioni, G.B. Pisani, G. Preparata, D. Primorac, L.J. Rangel Lemos, J.F. Rodriguez, M. Rotondo, J. Rueda, J. Salmonson, S. Shakeri, I. Siutsou, G. Vereshchagin, Y. Wang, J. Wilson, S.-S. Xue, E. Zaninoni.